Carnegie Mellon
Software Engineering Institute

Using EVMS with COTS-Based Systems

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June 2002

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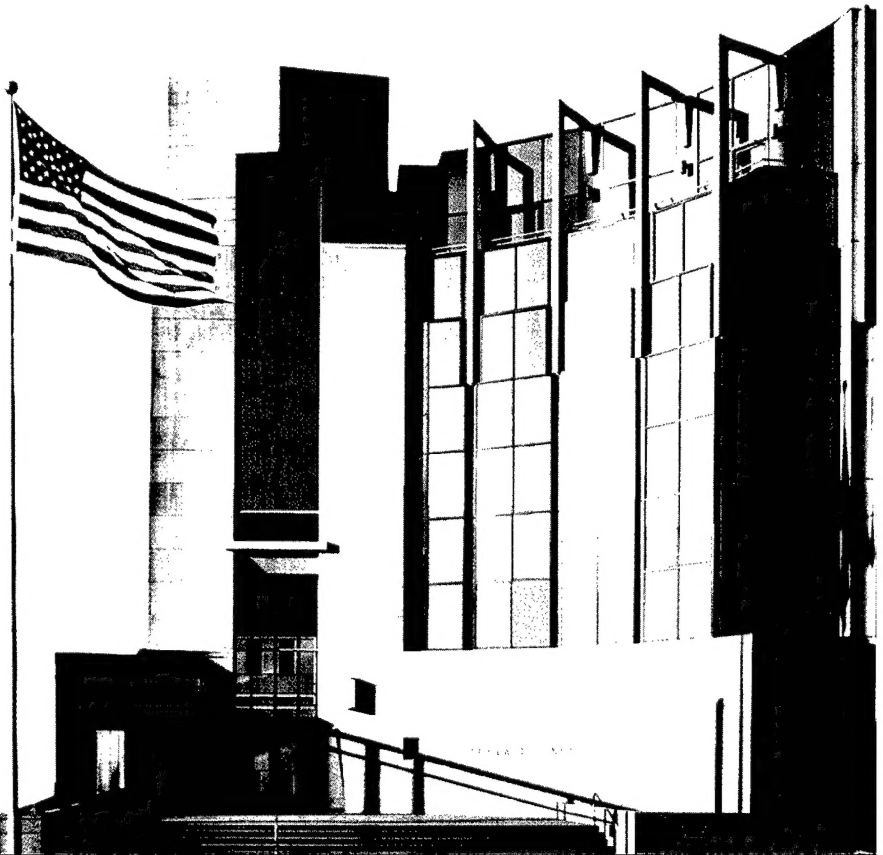

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FOR THE COMMANDER

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Abstract

With the increased use of commercial off-the-shelf (COTS) software products, managers of software development projects must deal with planning and tracking performance of projects that have new challenges and risks. A system developer may be required to integrate multiple COTS products with newly developed custom components and legacy system components. How are these new activities and tasks planned and monitored? Can traditional management methods be used?

Earned Value is a project management tool used extensively to plan and monitor performance against the plan. This paper's focus is on the use of Earned Value in the context of a COTS-Based System (CBS). It's written for an audience already familiar with Earned Value Project Management; only the basic definitions are discussed here with the associated terminology. A bibliography is included, offering good sources for obtaining more in-depth information on Earned Value history and methodology.

1 Introduction

With the increased use of COTS software products, managers of software development projects must deal with planning and tracking performance of projects with new challenges and risks. A system developer may be required to integrate multiple COTS products with newly developed custom components and legacy system components. How are these new activities and tasks planned and monitored? Can traditional management methods such as Earned Value and Work Breakdown Structures be used?

Since Earned Value can be used for any work that can be sized and scheduled, the answer to the question, "Can Earned Value be used for a COTS-based system (CBS)?" is obviously "Yes." More difficult questions include "What are the CBS-unique activities?" "Where in a development lifecycle do the CBS-unique activities fit?" "How is a time-phased project plan developed with COTS components in the mix of work?"

The SEI CBS initiative has documented the answer to the question, "What are the CBS-unique activities?" in Oberndorf [Oberndorf 00]. In this report we review the basic attributes of Earned Value. Then we map CBS activities to a system lifecycle, selected to illustrate how activities involving COTS products coincide with other defined system development stages and activities. We describe a basis for a lifecycle performance measurement plan and a CBS Work Breakdown Structure (WBS) template, and define a sample Earned Value plan for a typical CBS activity.

2 Basics of Earned Value

Earned Value is a technique that managers can use to control project cost and schedule. The concept of Earned Value is not new. It has been used in manufacturing industry for years, and in 1967 the Department of Defense (DoD) issued the Cost/Schedule Control Systems Criteria (C/SCSC) and mandated their use on systems developed for DoD. In 1997 the DoD approved a set of revised earned value criteria. [DoD 01]. Known as the "Earned Value Management System" (EVMS), it reduces the number of criteria from 35 to 32. With this change, EVMS progressed from being a government requirement to gaining private industry acceptance and use.

To properly use EVMS, a project performance baseline must be established. The elements of a performance baseline are scope, schedule, and cost, as shown in Figure 1.

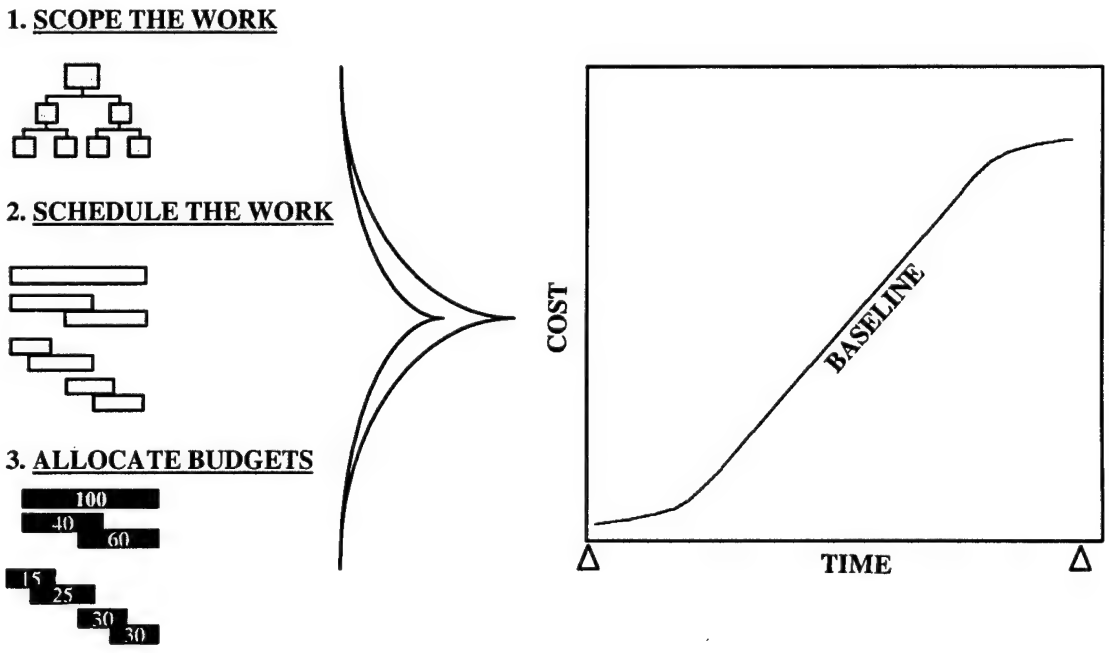

Figure 1: Establishing the Baseline

The integration of these elements forms the time-phased baseline with which progress can be tracked and predicted. The development of the project performance baseline is an iterative process for creating a bottom-up detailed plan. The iteration integrates the three elements of an Earned Value plan: scope, schedule and cost.

The scope of the work to be accomplished is usually defined and managed using a Work Breakdown Structure (WBS). A WBS represents all work that is within the scope of the software project. The WBS is represented as a hierarchical chart or an indented list that clearly shows the work, decomposed to three or four levels of detail.

Elements of the WBS are decomposed into manageable pieces called control accounts (CA). Control accounts are composed of work tasks called work packages (WP). A work package has schedule, budget, and organizational responsibility assigned. Frequently, a control account cannot be decomposed into work packages because the account is for future work for which the detail has not evolved. In such cases, Earned Value Planning Packages (PP) are defined instead as decompositions of the control account. A Planning Package evolves with the ongoing addition of detail as information becomes sufficiently available for planning future work. This feature of Earned Value allows for incremental planning, which is essential when developing a COTS project. The use of a CBS Work Breakdown Structure is explored later in this paper.

Once the scope of work is defined and responsibility assigned to an organizational entity, the defined work is planned and scheduled to the performing level; the required resources are estimated and budgets authorized. The sum of all the budgets for all planned work scheduled within a given time period is known as the Budgeted Cost for Work Scheduled (BCWS).

The performance against the plan is determined by calculating the value of the work accomplished at a point in time against the plan to produce the Budgeted Cost of Work Performed (BCWP). The Actual Cost of Work Performed (ACWP) is the summation of the costs actually incurred and recorded in accomplishing all work performed for the time period. The performance against the plan can be calculated with respect to schedule and cost. The difference between the planned value of the work scheduled and the value of the work accomplished for the same time period (BCWP – BCWS) is the schedule variance (SV), which can be used to calculate the percentage of the work a project set out to accomplish that was or was not accomplished in the scheduled time. The cost variance (CV) is defined as the difference between the value of the work accomplished and the actual cost incurred to perform the work (BCWP-ACWP); utilizing this parameter, the percentage of cost overrun or underrun can be calculated. The total estimated work in the plan is the sum of all the budgets and is called the Budget At Completion (BAC), while the Estimate At Completion (EAC) is the projected final cost and is based on a statistical prediction using the performance factors and indices. Figure 2 shows all these Earned Value elements.

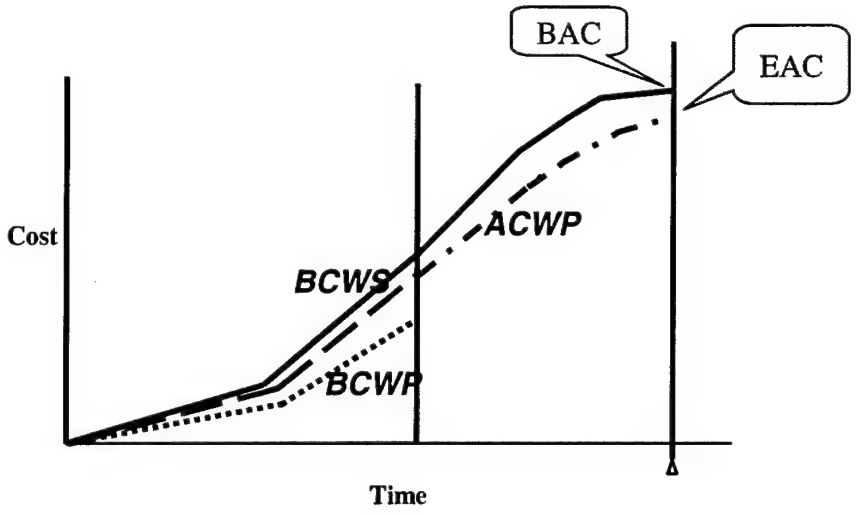

Figure 2: Earned Value Elements Plotted

3 COTS-Based Systems and Earned Value in a Complex System Environment

To establish that Earned Value can be employed for a CBS project, it is necessary to think about the activities that are new to the software development process as a result of using COTS products. In addition to just knowing activities, it is helpful to know when in the life of a system's development the activities relevant to the successful selection and implementation of COTS components are performed. Can we take an existing documented life cycle and map these CBS-unique activities into the life cycle with enough definition to create a "seamless" flow with other, more traditionally defined activities of the life cycle?

It is necessary to discuss creating an Earned Value management plan in the context of the life cycle and methodology, since many of the elements of a plan are dependent upon completion of specific artifacts or scheduled milestones of the development or maintenance cycle.

The framework chosen for this work is the iterative life cycle or Unified Framework presented in Walker Royce's *Software Project Management: A Unified Approach* [Royce 98] and *The Unified Software Development Process* by Jacobson, Booch, and Rumbaugh [Jacobson 99]. (See Appendix for a summary.) The Unified Framework allows for incremental planning and promotes planning with a degree of fidelity that matches the knowledge of the project at the time the plan is made. Plans evolve with the evolving system. The following paragraphs define the basics of the life cycle.

3.1 The Software Life-Cycle Framework

The Unified Framework is composed of two stages, four phases, and seven core workflows that are repeated in each iteration within a phase (see Figure 3). The stages are defined as the engineering stage and the production stage. It is during the engineering stage that the builders of the system bring the system to the point of an architectural baseline. Once the decision is made to build the system based upon a selected architecture, the model calls for moving from the engineering to the production stage, at which time the system is constructed and transitioned to the user.

The phases of the life cycle are Inception, Elaboration (together constituting the Engineering Stage), Construction, and Transition (together constituting the Production Stage). A generic

iteration is defined with the core workflows: Management, Requirements, Design, Implementation, Assessment, Deployment, and Environment.

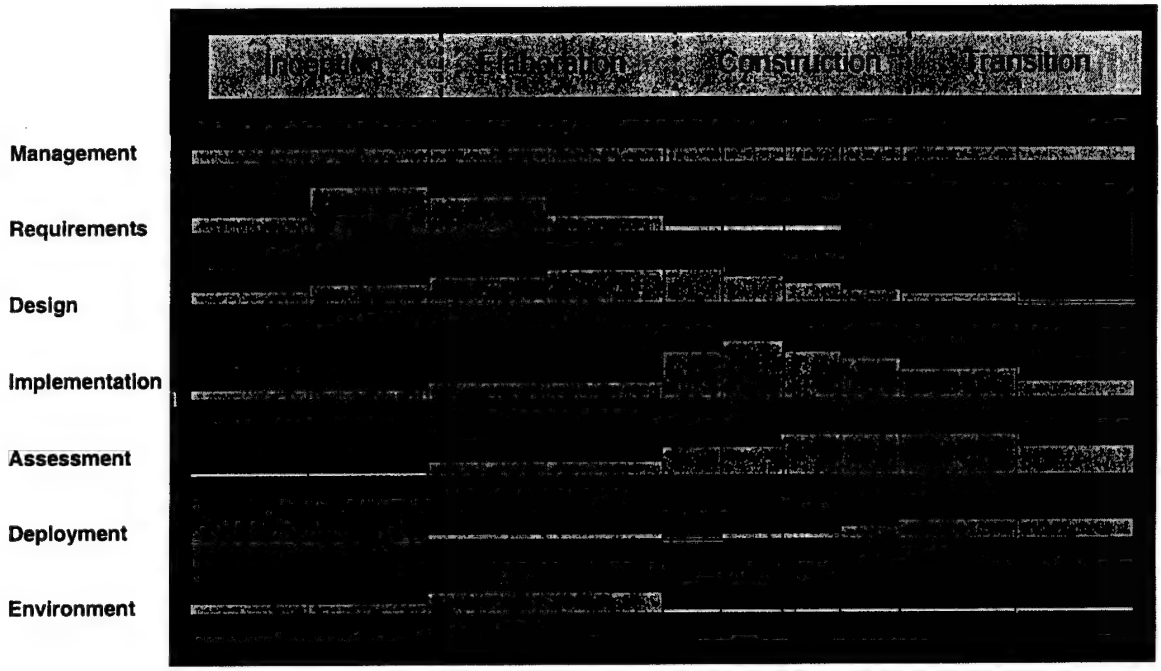

Figure 3: Iterative Life-cycle Activities from Royce [Royce 99]

The development of a system progresses through all the phases. Within a phase the work is performed by iterating through the workflows—one iteration can in some ways be compared to the traditional waterfall concept, although perhaps a better description is to call an iteration a mini-project. The focus of work related to the workflows varies depending upon the phase of development of the system. However, for each phase, work is defined for each workflow. For example, during the inception phase emphasis is on requirements, while in the construction phase emphasis is on implementation, but both workflows are part of both phases.

The major work product for a core workflow is a defined model of the system, where each model is simply the work products that represents some aspect of the system (e.g., design, code). All of the models for all of the core workflows are fleshed out as the development of the system progresses through the phases. The following paragraphs define at a high level the characteristics of the models.

These models are described in the Appendix. The data in the tables in the Appendix are summarized from both books used as references for the Unified Framework [Jacobson 99, Royce 98]. The mapping of CBS activities to Unified stages and activities contained in Section 4 makes more sense if we understand what is happening in the various phases with the custom development components of our complex system that also has COTS components. The Appendix provides a high-level chart for each of the phases, showing the activities within each phase, along with the key deliverables. The engineering workflows (i.e., those workflows that are not management activities) and artifacts are fully covered in *The Unified Software Development Process* [Jacobson 99].

4 COTS-Based Systems Activities Mapped to Unified Framework

A set of activities that are new or changed for COTS-based systems hs been compiled [Oberndorf 00]. These activities are categorized in "activity areas"; within each area are clusters of activities referred to as "activity sets," as depicted in Figure 4.

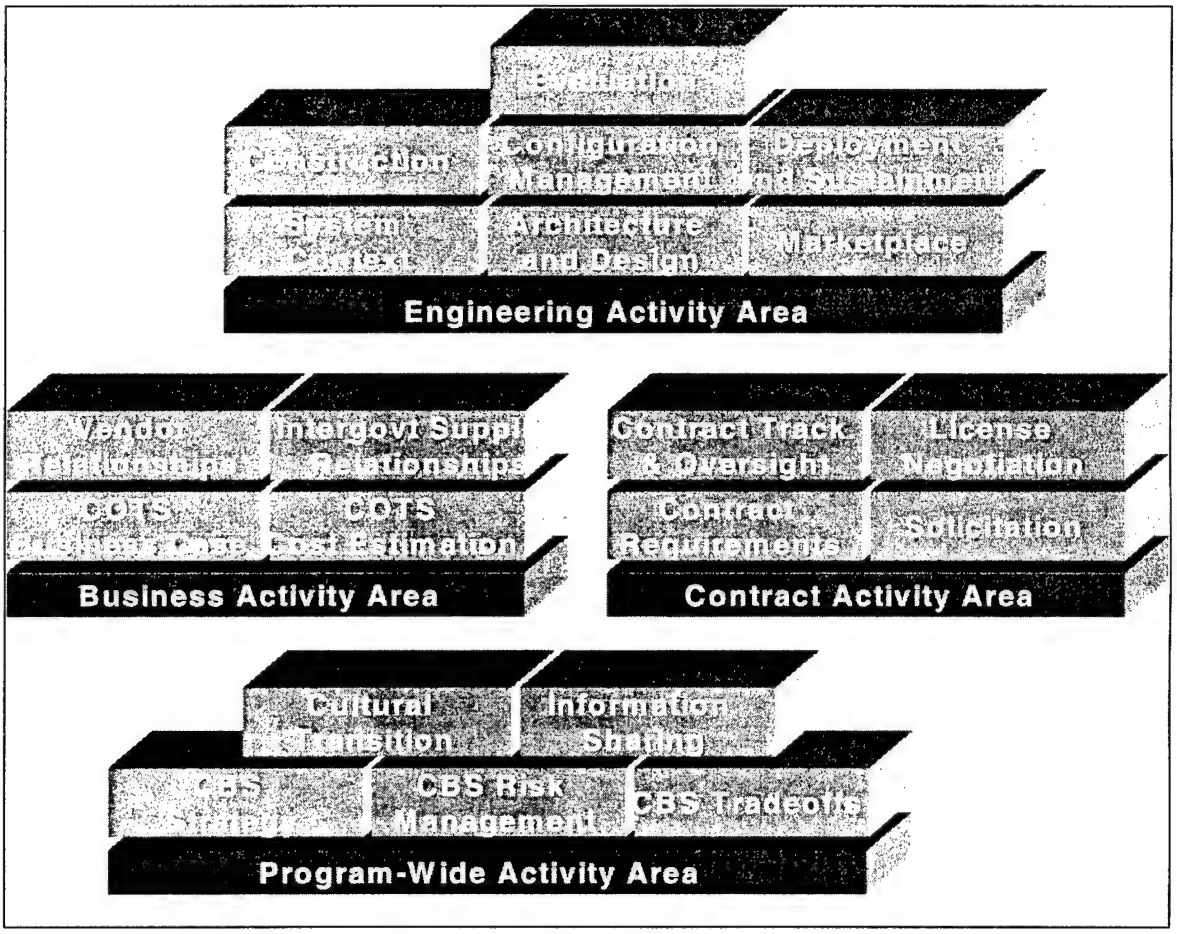

Figure 4: CBS Activity Sets

The activity areas are Engineering, Business, Contract, and Program-Wide. For this report, we have mapped the activities in the activity sets to the appropriate phases of the unified framework. This mapping is shown in Table 1.

A CBS activity may span multiple phases of the life cycle. This is accounted for in Table 1 where certain "activity cells" cross multiple "phase columns" of the table.

Table 1: CBS Activities Mapped to Framework

COTS Based Systems Activities		Engineering Stage		Production Stage	
CBS Area	**Activity Set**	**Inception**	**Elaboration**	**Construction**	**Transition**
Business	Vendor Relationships	Explore formal and informal vendor relationships.	Establish and maintain vendor relationships.	• Establish and maintain vendor relationships. • Periodically re-assess vendor relationships strategy.	
Business	Vendor Relationships ARTIFACTS	• License agreements • Documented relationships • Document formalizing strategy for maintaining the relationship			
Business	COTS Business Case	• Develop Preliminary business case. • Obtain and document stakeholder concurrence with critical success factors.	Make the COTS Business Case recommendation.	Monitor Business Case sensitivity analysis factors and revise COTS Business Case accordingly.	

COTS Based Systems Activities		Engineering Stage		Production Stage	
CBS Area	**Activity Set**	**Inception**	**Elaboration**	**Construction**	**Transition**
Business	COTS Business Case ARTIFACTS	• Preliminary COTS Business Case • Documented critical success factors.	• Completed COTS Business Case • Written critical success factors	• Revised COTS Business Case • Documented sensitivity analysis	
Business	Inter-government[1] Supplier Relationships from Acquirers' Point of Reference	• Explore formal and informal relationships with inter-government suppliers and their critical vendors. • Develop strategy.	Establish and maintain formal and informal relationships with inter-government suppliers and their critical vendors.	• Establish and maintain formal and informal relationships with inter-government suppliers and their critical vendors. • Periodically re-assess relationships with suppliers and their vendors.	

[1] Inter-government supplier relationships could be replaced with inter-*organizational* supplier relationships in a commercial setting.

COTS Based Systems Activities		Engineering Stage		Production Stage	
CBS Area	**Activity Set**	**Inception**	**Elaboration**	**Construction**	**Transition**
Business	Inter-government Supplier Relationships from Acquirers' Point of Reference ARTIFACTS	• License agreements with vendors • Document describing relationship with inter-government suppliers • Strategy document for inter-government relationships	• License agreements with vendors • Document describing relationship with inter-government suppliers • Strategy document for inter-government relationships		
Business	Inter-government Supplier Relationships from Supplier Point of View	• Document a strategy for NDI. • Establish user support groups.	• Market NDI • Establish and maintain relationships with acquirers	• Market NDI. • Establish and maintain relationships with acquirers. • Periodically re-assess govt. supplier relationships.	
Business	Inter-government Supplier Relationships from Supplier Point of View ARTIFACTS	• Strategy Document for marketing, maintaining and supporting NDI	• Marketing literature • Relationships documents such as memorandums of understanding (MOUs)		

COTS Based Systems Activities		Engineering Stage		Production Stage	
CBS Area	**Activity Set**	**Inception**	**Elaboration**	**Construction**	**Transition**
Business	COTS Cost Estimation	• Establish models and techniques for COTS cost estimate. • Estimate preliminary COTS costs. Collect actual cost data.	• Refine COTS cost models. • Refine COTS costs estimate. • Collect Actual cost data.		
Business	COTS Costs Estimation ARTIFACTS	• Cost estimation models and techniques • Preliminary cost estimates • Actual costs collected	• COTS Cost estimation models and techniques • Cost estimates • Actual costs collected		
Contract	License Negotiation	Investigate and negotiate Licenses.			
Contract	License Negotiation ARTIFACTS	Licenses Agreements			
Contract	Contract Requirements	Determine and establish contract requirements.	Assess impact of contract changes on CBS approach.		

Contract	Contract Requirements ARTIFACTS	Documented contract requirements	Documented impact analysis of contract changes with respect to COTS approach.		
Contract	Solicitation		Prepare acquirer estimates and criteria for products and services that include incentives.		
Contract	Solicitation ARTIFACTS		COTS relative parts of the RFP		
Engineering	System Context [denotes the collection of requirements (functional and non-functional, including the context of their end-user processes) and other constraints such as cost and schedule]	• Identify constraints. • Identify key user processes and product mismatches. • Participate in process/product tradeoff negotiations.	• Identify constraints. • Identify key user processes and product mismatches. • Promulgate tradeoffs.		

Engineering	System Context ARTIFACTS	System context tradeoff decisions document including rationale and commitments	• System context tradeoff decisions document including rationale and commitments • Revised affected documents (e.g. ORD, test plans)		
Engineering	Architecture and Design	Develop preliminary architecture in light of tradeoffs and marketplace.	• Validate architecture through prototypes or executable architecture approach. • Finalize CBS architecture and design in light of tradeoffs and marketplace. • Select COTS products.		
Engineering	Architecture and Design ARTIFACTS	• Preliminary CBS architecture and design • Alternative architecture and design	• Architectural prototype • Revised CBS architecture and design		
Engineering	Marketplace	• Create, maintain, and disseminate marketplace information. • Augment marketplace knowledge using results of prototypes and pilots.			

Engineering	Marketplace ARTIFACTS	• Information dissemination plan • Marketplace information (e.g., reports, database)	• Revised information dissemination plan • Revised Marketplace information (e.g., reports, database)		
Engineering	Construction	Prototype to discover product and system characteristics.	Perform preliminary integration of selected components.	• Tailor and integrate selected components. • Develop glue code. • Test components and system. • Receive and analyze product upgrades; incorporate as appropriate. • Isolate, analyze and resolve system faults.	• Receive and analyze product upgrades; incorporate as appropriate • Isolate, analyze and resolve system faults

Engineering	Construction ARTIFACTS	• Prototypes • Prototype results reports	• CBS Detailed Design • Prototype and accompanying documentation (e.g. user manuals, install procedures)	• Developed Source Code • Test Plans • Accompanying documents • Initial system implementation • Refined CBS architecture and detailed design • Produce upgrade impact analysis	• Revised: Source Code Test Plans • Accompanying documents • Initial system implementation • Refined CBS architecture and detailed design • Produce upgrade impact analysis
Engineering	Configuration Management	Identify configuration baselines.		• Revise configuration baseline. • Release new system versions.	Release new system versions.
Engineering	Configuration Management ARTIFACTS	Configuration baseline		• Updated configuration baselines • System Release	System Release

Engineering	Deployment and Sustainment	• Determine and implement strategies for system deployment and end user support of COTS products. • Manage incorporation of new product release and new products including management of licenses.	• Revise and implement strategies for system deployment and end user support of COTS products. • Manage incorporation of new product release and new products including management of licenses.
Engineering	Deployment and Sustainment ARTIFACTS	• Documented strategies and plans • License management plan • Supplier release and implementation plan • "Refreshed" prototype	• Revised strategies and plans • Revised License management plan • Revised Supplier release and implementation plan • "Refreshed" prototype
Engineering	Evaluation	Plan and execute evaluation tasks.	
Engineering	Evaluation ARTIFACTS	• Evaluation Plan • Evaluation Results	

Program Wide	Cultural Transition	• Assess readiness (including skill set required) to transition to CBS and provide training. • Develop and implement strategy for accomplishing the transition.	• Revise readiness assessment and training plan. • Implement and revise strategy for accomplishing the transition.
Program Wide	Cultural Transition ARTIFACTS	• Initial CBS needs analysis • COTS Training Plan • CBS transition strategy and plan • Transition lessons learned • Incentives and awards for use of CBS	• Revised CBS needs analysis • Revised COTS Training Plan • Revised CBS transition strategy and plan • Expanded Transition lessons learned • Incentives and awards for use of CBS
Program Wide	Information Sharing	Collect and share CBS information.	

Program Wide	Information Sharing ARTIFACTS	• Strategy and plan for CBS information sharing including models of usage, dissemination and maintenance • Mechanisms for collecting and sharing CBS information • Collected and shared information	• Revised strategy and plan for CBS information sharing including models of usage, dissemination and maintenance • Maintained mechanisms for collecting and sharing CBS information • Collected and shared information
Program Wide	CBS Tradeoffs	Make CBS Tradeoffs.	
Program Wide	CBS Tradeoffs ARTIFACTS	Tradeoff analyses including rationale and decisions	
Program Wide	CBS Strategy	Formulate CBS Strategy.	Revise CBS Strategy.
Program Wide	CBS Strategy ARTIFACTS	CBS Strategy including technology refresh plan	Revised CBS Strategy including technology refresh plan
Program Wide	CBS Risk Management	Identify and manage CBS risks.	
Program Wide	CBS Risk Management ARTIFACTS	CBS risks identification and analysis	

5 The COTS-Based System Work Breakdown Structure

According to Royce, traditional WBSs are prematurely structured around the system design. This makes for a plan that is difficult and expensive to change. A WBS that is organized around the process rather than the design of the system can evolve without breaking the entire structure. An evolutionary WBS, then, is one that accounts for the evolution of the WBS itself and contains planning tasks in each major phase. These planning tasks provide the structure to elaborate the next phase without breaking the WBS. The first-level elements of an evolutionary WBS are the core workflows, the second-level elements are defined for each of the phases within the life cycle, and the third-level elements are defined for the activities within the phase that produce the artifacts.

The default WBS with the Unified Framework [Royce 98] description is used as the starting point in the following CBS WBS (Table 2). The CBS activities have been inserted into the template and *italicized*. Each system is unique, and the WBS is specific to the system. This generic example provides a framework that can be exploited and tailored for a real project.

Observe that planning occurs throughout the life cycle; each phase creates a plan for the next phase, which is then detailed when the phase begins. This type of management cycle can use the concepts of Earned Value to build the first plan with Planning Packages that are elaborated when the information is available to make a more detailed plan.

Table 2: Software WBS with COTS-Based System Activities

1. Management

1.1. Inception phase management

1.1.1. Business case development

1.1.2. COTS business case development

1.1.2.1. Preliminary COTS business case development

1.1.2.2. Critical COTS success factors development

1.1.3. Vendor relationships

1.1.3.1. Vendor relationships exploration

1.1.3.2. License agreements exploration

1.1.4. Inter-government supplier relationships

1.1.4.1. Inter-government supplier relationship exploration

1.1.4.2. Inter-government agreements exploration

1.1.5. COTS cost estimates

1.1.5.1. COTS cost estimate cost model and technique establishment

1.1.6. COTS license negotiation

1.1.7. Contract requirements establishment

1.1.8. Elaboration phase release specification

1.1.8.1. Plan CBS strategy (including vendor relationship strategy)

1.1.9. Elaboration phase WBS baselining

1.1.10. Software development plan

1.1.11. Inception phase project control and status assessments

1.2. Elaboration phase management

1.2.1. Construction phase release specification

1.2.2. COTS business case development

1.2.2.1. COTS business case recommendation

1.2.2.2. Critical COTS success factors agreement

1.2.3. Vendor relationships establishment and maintenance

1.2.3.1. License agreements and documented relationships maintenance

1.2.4. Inter-government supplier relationships maintenance

1.2.5. COTS cost estimate

1.2.5.1. COTS cost estimate refinement

1.2.5.2. COTS cost data collection

1.2.6. CBS Contract Solicitation

1.2.6.1. Preparation of estimates for products and services

1.2.7. Construction phase WBS baselining

1.2.8. Elaboration phase project control and status assessments

1.3. Construction phase management

1.3.1. Transition phase planning

1.3.2. COTS business case development

1.3.2.1. Sensitivity analysis factors monitoring

1.3.2.2. COTS business case revision

1.3.3. Vendor relationships maintenance

1.3.3.1. Formal and informal relationships strategy re-assessment

1.3.3.2. License agreement maintenance

1.3.4. Inter-government supplier relationships maintenance

1.3.4.1. Formal and informal relationships strategy re-assessment

1.3.5. CBS culture transition

1.3.5.1. Readiness assessment

1.3.5.2. Strategy for transition development and implementation

1.3.6. Transition phase WBS baselining
1.3.7. Construction phase project control and status assessments
1.4. Transition phase management
1.4.1. Next generation planning
1.4.1.1. CBS migration strategy and plan
1.4.1.2. Migration lessons learned
1.4.2. Transition phase project controls and status assessments
1.4.3. COTS business case maintenance and revision
1.4.4. Intergovernment supplier relationships maintenance
1.4.5. Vendor relationships maintenance
1.4.6. CBS culture transition for CBS development
1.4.6.1. Initial CBS needs analysis
1.4.6.2. COTS training plan
1.4.6.3. CBS test plans development

2. Environment

2.1. Inception phase environment specification
2.1.1. CBS development/integration environment specification
2.1.2. CBS test-bed specification
2.1.3. CBS information sharing repository and data specification
2.2. Elaboration phase environment baselining
2.2.1. Development environment installation and administration
2.2.1.1. CBS development/integration environment installation and administration
2.2.1.2. CBS test-bed installation and administration
2.2.1.3. CBS information repository installation, data population, and administration
2.2.2. Development environment integration and custom toolsmithing
2.2.2.1. CBS development/integration environment integration, custom toolsmithing, and maintenance
2.2.2.2. CBS test-bed environment integration, custom toolsmithing, and maintenance
2.2.2.3. CBS information sharing repository integration, custom toolsmithing, and maintenance
2.2.3. Software change order data base formulation
2.2.3.1. CBS development/ integration change order data base formulation
2.2.4. Configuration Management installation and administration
2.2.4.1. CBS development/integration environment configuration management installation and administration
2.3. Construction phase environment maintenance
2.3.1. Development environment installation and administration
2.3.1.1. CBS development/integration environment installation, administration, and maintenance
2.3.1.2. CBS test-bed administration and maintenance
2.3.1.3. CBS information sharing repository installation, administration, and maintenance
2.3.2. Software change order databases maintenance
2.3.2.1. CBS development/integration installation maintenance
2.3.3. Configuration management installation and administration
2.3.3.1. CBS development/integration installation and maintenance
2.4. Transition phase environment maintenance
2.4.1. Development environment maintenance and administration

2.4.1.1. CBS development/integration installation maintenance
2.4.1.2. CBS test-bed maintenance
2.4.1.3. CBS information repository maintenance
2.4.2. Software change order database maintenance
2.4.2.1. CBS development/integration installation maintenance
2.4.3. Maintenance environment packaging and transition
2.4.3.1. CBS development/integration installation packaging and transition
2.4.3.2. CBS test-bed packaging and transition
2.4.3.3. CBS information repository packaging and transition
2.4.4. Configuration management installation and administration
2.4.4.1. CBS development/integration installation maintenance

3. Requirements

3.1. Inception phase requirements development
3.1.1. Vision specification
3.1.2. CBS system context[2] tradeoff
3.1.3. CBS Marketplace
3.1.3.1. Marketplace information creation, dissemination, refresh
3.1.4. Use case modeling
3.1.4.1. CBS feasibility demonstration prototype
3.2. Elaboration phase requirements baselining
3.2.1. Vision baselining
3.2.2. CBS process and product tradeoff negotiation
3.2.3. CBS process and product tradeoff baselining
3.2.4. Use case model baselining
3.3. Construction phase requirements maintenance
3.4. Transition phase requirements maintenance

4. Design

4.1. Inception phase architecture prototyping
4.1.1. CBS architecture and design
4.1.1.1. Preliminary CBS architecture development
4.1.1.2. Alternative CBS architecture development
4.1.2. CBS Marketplace
4.1.2.1. Marketplace information creation, dissemination, refresh
4.2. Elaboration phase architecture baselining
4.2.1. Architecture design modeling
4.2.1.1. CBS architectural prototyping
4.2.1.2. System tradeoff decision and commitments
4.2.1.3. COTS product selections
4.2.2. Software architecture description
4.2.2.1. CBS architecture and design description
4.3. Construction phase design modeling
4.3.1. Architecture design model maintenance
4.3.2. CBS architecture and design
4.3.2.1. CBS architecture and design maintenance
4.3.2.2. COTS product upgrade impact analysis
4.3.3. Component design modeling
4.4. Transition phase design maintenance

---

[2] System context denotes the collection of requirements (functional and nonfunctional, including the context of their end-user processes) and other constraints such as cost and schedule.

5. Implementation

5.1. Inception phase component prototyping

5.1.1. CBS construction

5.1.1.1. COTS prototypes development

5.2. Elaboration phase component implementation

5.2.1. Critical component coding demonstration integration

5.2.1.1. COTS demonstration prototype integration

5.2.1.2. COTS product selection

5.3. Construction phase component implementation

5.3.1. Initial release(s) component coding and stand-alone testing

5.3.1.1. COTS product tailoring

5.3.1.2. COTS products upgrades receipt and analysis

5.3.1.3. CBS component glue code implementation

5.3.2. Alpha release component coding and stand-alone testing

5.3.2.1. COTS product tailoring

5.3.2.2. COTS product upgrades receipt and analysis

5.3.2.3. CBS component glue code implementation

5.3.3. Beta release component coding and stand-alone testing

5.3.3.1. COTS product tailoring

5.3.3.2. COTS product upgrades receipt and analysis

5.3.3.3. CBS component glue code implementation

5.3.4. Component maintenance

5.3.4.1. COTS product upgrades analysis

5.3.4.2. COTS product upgrades configuration management

5.4. Transition phase component maintenance

5.4.1. CBS deployment and sustainment

5.4.1.1. New COTS product release management

5.4.1.2. System deployment and end user support strategies implementation

6. Assessment

6.1. Inception phase assessment planning

6.2. Elaboration phase assessment

6.2.1. Test modeling

6.2.2. Architecture test scenario implementation

6.2.3. Demonstration assessment and release descriptions

6.3. Construction phase assessment

6.3.1. Initial release assessment and release description

6.3.2. Alpha release assessment and release description

6.3.3. Beta release assessment and release description

6.4. Transition phase assessment

6.4.1. System release assessment and release descriptions

7. Deployment

7.1. Inception phase deployment planning

7.1.1. CBS deployment and sustainment

7.1.1.1. CBS deployment/support strategy development

7.1.1.2. Supplier release and implementation plan development

7.1.1.3. License management plan development

7.2. Elaboration phase deployment planning

7.2.1. CBS deployment and sustainment

7.2.1.1. CBS deployment strategies revision and implementation

7.2.1.2. Supplier release and implementation plan revision
7.2.1.3. License management plan revision

7.3. Construction phase deployment

7.3.1. User manual baselining

7.3.2. CBS deployment and sustainment

7.3.2.1. New product release and license management
7.3.2.2. CBS implementation strategies implementation

7.4. Transition phase deployment

7.4.1. Product transition to user

7.4.2. CBS deployment and sustainment

7.4.2.1. CBS end-user support management

6 A Simple COTS-Based System Example Using Product Evaluation as a Stand-Alone Project

Our premise is that if work can be decomposed into manageable pieces that can be estimated for effort and schedule, then Earned Value techniques can be applied. The following example shows an Earned Value plan for a small product evaluation effort in a CBS project. Desktop tools that included spreadsheets and Microsoft Project were used for this example.

The process used a survey of the marketplace for a web browser suitable for a large Management and Control System. The goal of the evaluation process was to compare features of candidate products against the set of requirements. The selection process included a task to map the features of each candidate product against the requirements. This work package is called "Develop Feature Maps" in the WBS. A team at the SEI performed this COTS evaluation work. At the time the project was executed, it was not managed using Earned Value. But we have been able to reconstruct the work packages of the project from historical data to build this plan. The example is not a case study: the WBS items represent the actual work breakdown that was used; the other parameters have been added for illustration purposes.

6.1 Profile of the Evaluation Project

An evaluation process was followed that consisted of work and work products defined by the Work Breakdown Structure in Figure 5. The WBS is illustrated here as an indented list. It should be noted that this exercise was not embedded in a project that was planned against the Unified Framework. As can be seen in the activities chart in Table 1, an evaluation activity for CBS can occur in any phase of a project. These WBS elements for the evaluation (shown here at Level 3) would then be at Level 4 or Level 5 of a larger project WBS.

1. WWW Server Evaluation
    1.1. Conduct Market Survey
        1.1.1.Identify Candidates
        1.1.2.Develop Product Categories
        1.1.3.Develop Feature Maps
    1.2. Develop Evaluation Criteria
        1.2.1.Develop Evaluation Criteria Check-lists
    1.3. Develop Assessment Plan
            1.3.1.1. Plan Assessment Technique

1.3.1.2. Develop Assessment Schedule

1.3.2. Conduct Assessment

1.3.2.1. Vendor Literature

1.3.2.2. Model Problem

1.3.2.3. Product Profile

1.3.3. Synthesize Results

1.3.3.1. Compile Assessment Results

1.3.3.2. Conduct Review

Figure 5: WBS for WWW Server Evaluation

6.2 Estimating the Effort for CBS Development

A complete Earned Value plan using the WWW Server Evaluation task elements is shown in as an example. Once resources were assigned to the schedule, the tasks were scheduled using Microsoft Project. The task resource usage report from Microsoft Project supplies the time-phased data (effort in hours), which can then be input into an Excel workbook, which is used to track the progress.

The Earned Value plan is captured in a spreadsheet (Figure 7) that has entries for the plan (BCWS), the earned value (BCWP), and the actual cost (ACWP). Progress against the plan can be entered into the sheet on a weekly basis (Figure 8) and plotted as shown in Figure 9. Many tools are available to plan and track a project using EVMS; the job can also be done with a suite of desktop office products.

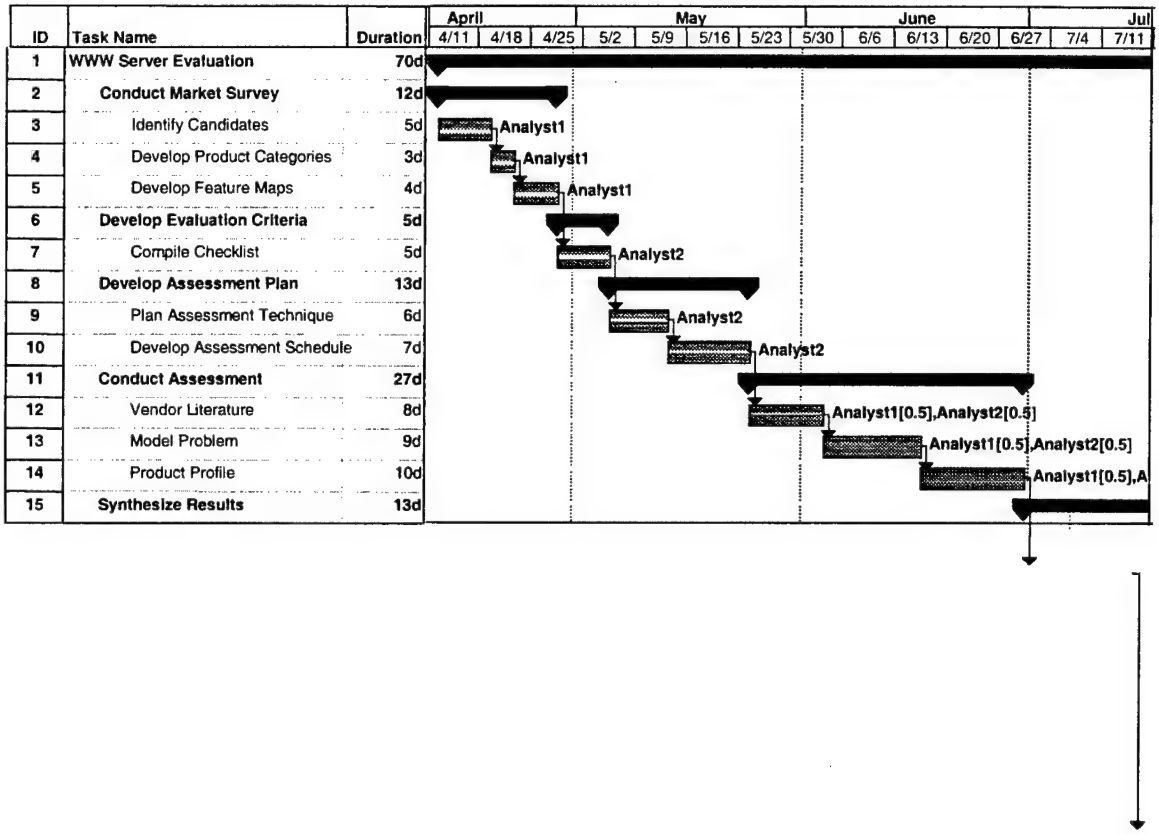

Figure 6: Scheduled Work

Work Components	Est Sloc	Other Hours	Earnable Units	<Mile-stone 1>	EV	<Mile-stone 2>	EV	<Mile-stone 3>	EV	Total Earned	% Complete
Earnable percentages by Milestones				30%		40%		30%			
Component #1 Conduct Market Survey	**0**	**96**	**96**	**100%**	**28.8**	**0%**	**0**	**0%**	**0**	**28.8**	**30.00%**
Identify Candidates		40	40	1	12.0		0		0	12.0	30.00%
Develop Product Categories		24	24	1	7.2		0		0	7.2	30.00%
Develop Feature Maps		32	32	1	9.6		0		0	9.6	30.00%
Component #2 Develop Evaluation Criteria	**0**	**40**	**40**	**50%**	**6.0**	**0%**	**0**	**0%**	**0**	**6.0**	**15.00%**
Develop Evaluation Criteria Check Lists		40	40	0.5	6.0		0		0	6.0	15.00%
Component #3 Develop Assessment Plan	**0**	**104**	**104**	**0%**	**0**	**0%**	**0**	**0%**	**0**	**0**	**0.00%**
Plan Assessment Technique		48	48		0		0		0	0	0.00%
Develop Assessment Schedule		56	56		0		0		0	0	0.00%
Component #4 Conduct Assessment	**0**	**216**	**216**	**0%**	**0**	**0%**	**0**	**0%**	**0**	**0**	**0.00%**
Vendor Literature		64	64		0		0		0	0	0.00%
Model Problem		72	72		0		0		0	0	0.00%
Product Profile		80	80		0		0		0	0	0.00%
Component #5 Synthesize Results	**0**	**192**	**192**	**0%**	**0**	**0%**	**0**	**0%**	**0**	**0**	**0.00%**
Compile Assessment Results		176	176		0		0		0	0	0.00%
Conduct Review		16	16		0		0		0	0	0.00%
Total	**0**	**648**	**648**	**18%**	**34.8**	**0%**	**0**	**0%**	**0**	**34.8**	**5.37%**

Figure 7: Earned Value Plan Spreadsheet

Week Beginning		4/4	4/11	4/18	4/25
Week End		4/10	4/17	4/24	5/1
Task BCWS	**Component #1 Conduct Market Survey**	0	32	72	96
Task ACWP		0	0	0	0
Task BCWP		0	19.68	28.8	0
Task BCWS	**Component #2 Develop Evaluation Criteria**	0	0	0	16
Task ACWP		0	0	0	0
Task BCWP		0	6	6	0
Task BCWS	**Component #3 Develop Assessment Plan**	0	0	0	0
Task ACWP		0	0	0	0
Task BCWP		0	0	0	0

Figure 8: Time-Phased EV Plan Implemented with Spreadsheet Tool to Collect Measurement

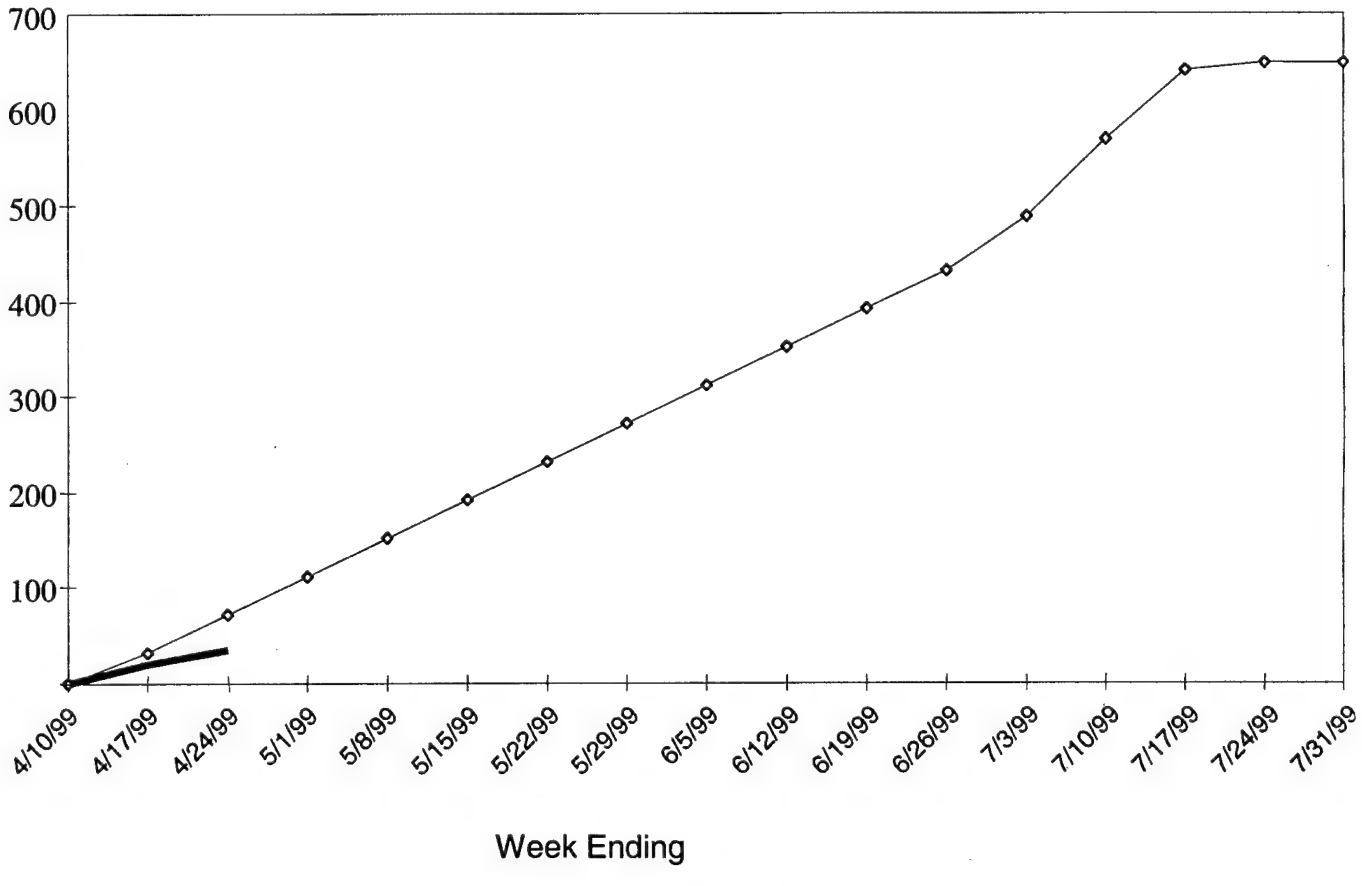

Figure 9: Earned Value Plan

7 Conclusion

We opened this paper by answering the question, "Can Earned Value be used in a COTS-based system development?" with a "yes." The work reported in this paper confirms that "yes" is the correct answer. We have illustrated in the preceding sections both why the answer is "yes" and how this application of EVM can be accomplished.

There are many COTS-unique activities that must be integrated into our traditional approaches if we are to succeed with COTS-based systems. Earned Value has features, such as the planning packages, that will make it easier to plan an evolving development lifecycle. In addition, the traditional Work Breakdown Structure can be composed of elements that reflect the *process* rather than the system design. A process-based WBS is particularly advantageous for COTS-based systems: the change of a COTS product or technology can affect the design of the system, which would disturb the whole management process if the WBS were design based.

Acronym List

ACWP	actual cost of work performed
BAC	budget at completion
BCWP	budgeted cost of work performed
BCWS	budgeted cost for work scheduled
CA	control account
CBS	COTS-based system
COTS	commercial off-the-shelf
CV	cost variance
EAC	estimate at completion
EV	earned value
EVMS	earned value management system
IOC	initial operational capability
MOU	memorandum of understanding
NDI	non-developmental item
ORD	operational requirements document
PP	(earned value) planning package

RFP	request for proposal
SV	scheduled variance
WBS	work breakdown structure
WP	work package

Appendix: Key Activities by Phase

Adapted from *The Unified Software Development Process* by Jacobson, Booch, and Rumbaugh [Jacobson 99]

<table>
<tr><th colspan="2">Inception Phase</th></tr>
<tr><th>Inception Phase Activities</th><th>Key Deliverables of Inception Phase</th></tr>
<tr><td>

General Description and goals: The goals of the inception phase is to establish the business case, scope the system, sketch an architecture, identify critical risks, develop a proof of concept prototype.

- **Requirements:** Identify 50% of use-cases analyze/prototype small percentage for proof of concept during this phase.
  1. List candidate requirements for system feature list.
  2. Understand system context.
  3. Capture pertinent functional requirements.
  4. Capture related nonfunctional requirements.
- **Analysis:** Build initial analysis model that will be the basis of the early design model. This model reveals the shared resources among the selected use-cases for this phase.
  1. Analyze a use-case.
  2. Build simple analysis model showing shared resources among selected use-cases.
- **Design**: Sketch a design model for the candidate architecture.
  1. Develop initial design model.
  2. Identify interfaces between subsystems/classes.
- **Implementation:** In most cases the implementation flow is not required/used in the inception phase.
- **Test**: Small amount of activity in the test flow for the inception phase if any.

</td><td>

- First draft of the business case
- First version of a business model – sets context of the system
- A feature list
- First draft of a candidate architecture description
- Proof of concept exploratory prototype – demonstrating use of the system
- Initial risk list and use-case ranking
- Beginning of plan for entire system
- First cut of use-case model, analysis model, and design model

</td></tr>
</table>

Develop some tentative test plans. • **Select the development environment.** • **Develop the initial business case.**	

Elaboration Phase

Elaboration Phase Activities

General Description and goals: Iterate to capture about 80% or the requirements and detail a small percentage to develop the executable architecture baseline.

- **Requirements**: Goal is to capture about 80% of the requirements, implement and test scenarios to develop the architectural baseline.
  1. Find use-cases necessary for architectural baseline – detail only these cases.
  2. Prototype user-interfaces.
  3. Prioritize use-cases.
  4. Detail use cases needed to understand requirements.
- **Analysis:** Build on the analysis model that was begun in the Inception Phase. Perform the analysis activities for use cases that are architecturally significant. These activities include analyze a use case, analyze a class, and analyze a package.
- **Design:** Design the architecturally significant use cases, classes, and subsystems. This usually means less than 10% of the use-case mass.
- **Implementation:** Implement and test the components that were designed. The results are the architectural baseline.
- **Test:** Plan and execute tests that ascertain that the components on all levels work for the architectural baseline. Components are tested as they become available and integrated for the build test.
- **Make the business case.**
- **Plan the construction phase.**

Key Deliverables of Elaboration Phase

- Complete business model
- New version of all models
- Executable architectural baseline
- Architecture description
- Updated risk list
- Project plan for construction and transition phases
- Preliminary user manual (optional)
- Completed business case

Construction Phase

Construction Phase Activities

General Description and goals: Take the architectural baseline through iterations to develop a software product ready for the initial operational baseline.

- **Requirements:** Perform the requirements capture for the small % (hopefully <20%) that was not identified and detailed in the elaboration phase.
- **Analysis:** Perform analysis steps to extend the model to include the addition requirements identified in this phase.
- **Design:** Design and implement the remaining 90% of the use cases – those that were not implemented to develop the architectural baseline.
- **Test:** Design and perform test cases to test the system. This is performed on a build basis.
- **Prepare first cut of user manuals.**
- **Plan the transition phase.**

Key Deliverables for Construction Phase

- The executable software
- All models/artifacts of the system
- Maintained architecture description
- Preliminary user manual
- Business Case – reflecting situation at the end of the phase

Transition Phase	
Transition Phase Activities	Key Deliverables for Construction Phase
General Description and goals: Establish the product in the operational environment. The activity is low in all the core workflows for the transition phase. The core flows are concerned with responding to feedback to correct problems. Other parallel activities are performed as listed below. • **Prepare the actual Beta Release from the IOC of the construction phase.** • **Install at site.** • **Act on feedback to correct defects.** • **Complete the artifacts/manuals.** • **Determine when project ends.** • **Assess the transition phase.**	• The executable software, installation software • Legal documents, license documents, waivers • All models completed for the baseline • Complete architecture description • End-user, operator, system administrator manuals • Customer support references

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13. ABSTRACT (MAXIMUM 200 WORDS)

With the increased use of commercial off-the-shelf (COTS) software products, managers of software development projects must plan and track performance of projects that have new challenges and risks. A system developer may be required to integrate multiple COTS products with newly developed custom components and legacy system components. How are these new activities and tasks planned and monitored? Can traditional management methods be used?

Earned Value is a project management tool used extensively to plan and monitor performance against the plan. This paper's focus is on the use of Earned Value in the context of a COTS-Based System (CBS). It's written for an audience already familiar with Earned Value Project Management; only the basic definitions are discussed here with the associated terminology. A bibliography is included, offering good sources for obtaining more in-depth information on Earned Value history and methodology.

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